AD-A042 850 MASSACHUSETTS INST OF TECH CAMBRIDGE DEPT OF NUCLEAR--ETC F/G 10/2
TRANSMISSION AND DISTRIBUTION COST DATA FOR USE IN COMMUNITY TO--ETC(U)
MAY 77 S B GOLDMAN, F R BEST, M W GOLAY DAAK02-74-C-0308

UNCLASSIFIED USAFESA-RT-2037 NL

1 OF 1

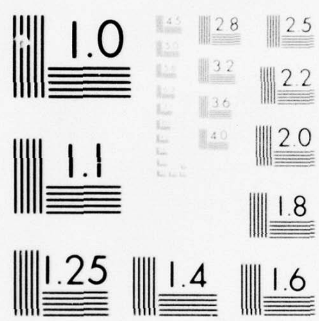
AD A042 850

END

DATE FILMED

9 -77

DDC


1.0
4.5
5.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

(18) USAFESA-RT-2037 (19)

(12)

(6) TRANSMISSION AND DISTRIBUTION COST DATA FOR USE IN COMMUNITY TOTAL ENERGY SYSTEM ANALYSIS WITH FORT KNOX, KENTUCKY AS AN EXAMPLE.

(10) Steven B./Goldman,
Frederick R./Best
Michael W./Golay
Department of Nuclear Engineering
Massachusetts Institute of Technology
Cambridge, MA 02139

(11) 30 May 1977 (15) DAAK02-74-C-0308 (12) 25p.

(9) Final Report, Jun 76 - May 77, (16) 4A762731AT41

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

(17) T6

Prepared for:

US ARMY FACILITIES ENGINEERING SUPPORT AGENCY
Research and Technology Division
Fort Belvoir, VA 22060

401 186

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER FESA-RT-2037	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Transmission and Distribution Cost Data for Use in Community Total Energy System Analysis with Fort Knox, Kentucky as an Example		5. TYPE OF REPORT & PERIOD COVERED Topical Report Jun 76-May 77
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Steven B. Goldman Frederick R. Best Michael W. Golay		8. CONTRACT OR GRANT NUMBER(s) DAAK02-74-C-0308
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Nuclear Engineering Massachusetts Institute of Technology Cambridge, MA 02139		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 6.27.31; 4A762731AT41; T6; 013
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Facilities Engineering Support Agency Research and Technology Division Fort Belvoir, VA 22060		12. REPORT DATE 30 May 1977
		13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Economic Analysis; Electrical Distribution Costs

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Topical Report

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ABSTRACT

The purpose of this study is to estimate the capital costs of an electrical Transmission and Distribution (T&D) system. These costs actually refer to the marginal costs of modifying an existing T&D system to meet the requirements of a future planned Total Energy System which would be of a different capacity than that currently in place. The amount of equipment required for a given T&D system configuration is first determined. Then unit costs are derived and applied to the equipment needs, thus generating total T&D system costs. Marginal costs of the modified T&D system can then be computed. It is found that marginal T&D costs are not insignificant when analyzing the economics of power generation, especially in the construction of electric-intensive Total Energy Systems.

T and D

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

In a utility system, the electrical transmission and distribution system delivers electric power from the point of generation to the point of final consumption. It must have sufficient capacity to meet the peak demands of the area it serves and, simultaneously, to satisfy local energy demand patterns within the service area. Transmission and distribution (T&D) costs contribute significantly to the total costs of providing electrical service; historically, T&D comprises between 1/3 and 2/3 of the costs of producing and delivering electricity. Thus, T&D cannot be ignored when analyzing the economics of power generation.

The aim of this report is to estimate the capital costs of the electrical T&D system which could be used as part of a Total Energy System (TES).[1] These costs actually refer to the marginal costs of modifying an existing T&D system to meet the requirements of a future planned Total Energy System which would be of a different capacity than that currently in place. The method of analysis is as follows:

1. Determine the unit costs for the T&D equipment. This can be accomplished with a literature survey. The equipment under consideration includes:

   A. Transmission lines, which carry the electric power from the generating stations to the load centers of the demand network;

B. Transmission substations, which reduce the voltage at which power is transmitted in the distribution system;

C. Primary Distribution lines, which carry the power to the local area being served;

D. Distribution substations which further reduce the voltage at which power is transmitted for local distribution;

E. Line transformers, which bring the distribution power voltage down to consumer use levels; and

F. Electric energy consumption meters.

Note that the distinction between transmission substation equipment and distribution substation equipment is primarily one of degree rather than kind.

2. Calculate the cost of installing a T&D system in a base-case TES, using current electrical demand data.
3. Calculate the cost of installing a T&D system in a TES which must meet the requirements of the future demand with a given mix of thermal and electrical energy supply for each of the configurations of interest.
4. Subtract the base case costs from those of the case under study. This differential cost will give the marginal cost of changing the base case TES T&D system to the TES configuration under study.

The details of these steps are developed in the following discussion. Chapter 2 presents the literature survey and the data used in the analysis resulting from that survey. Chapter 3 presents the analyses for an example base case (Fort Knox currently) and for possible Fort Knox future TES scenarios. Finally, Chapter 4 discusses the results of the analyses.

2. DATA

In this chapter, the data utilized in the analyses are compiled. As stated previously, a T&D system is composed of:

A. Transmission lines,

B. Transmission substations,

C. Primary distribution lines,

D. Distribution substations,

E. Line transformers, and

F. Meters.

First, one must determine the amount of equipment required for a given T&D system configuration. Then unit costs must be derived which, when applied to the equipment needs, will generate total T&D system costs. Based on this, one can determine the resulting marginal costs.

Most of the above data is summarized in the report Electric Power Transmission and Transmission Distribution Systems: Costs and Their Allocation by M. Baughman and D. Bottaro.[2] Briefly, the authors of this report have accumulated U.S. electric utility cost data and have performed linear regression analysis on these data to develop simple equations which relate the amount of equipment in each of the above categories that would be required in a large scale T&D system. In a subsequent literature survey, the unit costs of the above equipment have been obtained by region. Finally, a similar regression analysis has been performed to compute yearly normalized operation and maintenance (O&M) costs. The data base from which the equations are generated is comprised of information from privately owned U.S. electric utilities using their annual statistics from 1965 onwards. Two broad customer classes are considered. The first is "small light and power," which consists of commercial and residential customers. The second is "large light and power" which consists of industrial customers who take their electric power directly from the transmission system. For further details, the reader is directed to Ref. (2). Only the results of that report as applicable are used herein.

The input data to the above equations consist of the annual electrical sales to, and the number of users of, each of the two customer classes. In addition, data regarding the area and load density of the region served are required. The input parameters will be derived as used in the analyses in Chapter 3 in order to preserve clarity.

The equations in Ref. (2) were derived on a regional basis. As such, there are questions as to the applicability of these results to a relatively small, high density area such as Fort Knox. Conversations with one of the authors

(D. Bottaro) have shown that the equations were in fact derived for a geographical region and that the constants might not apply to a small high load-density area. However, the author notes that the marginal costs of electric utility systems are approximately regionally independent. Thus, the Baughman-Bottaro equations can be utilized in marginal cost analysis. As has been stated previously, the specific input parameters are computed as required in Chapter 3.

3. ANALYSIS

3.1 Input Parameters

The input parameters to the equipment equations consist of combinations of sales data, numbers of users, and service area sizes. These parameters are presented in the following form: the parameter name as used in the equations, its definition, and the method of derivation. The required parameter values are obtained for the example of Fort Knox, Ky.

CUSRSM is the number of residential and small light and power customers on the system. There are few, if any, industrial users of power on the typical military base. As such, all users of electricity are considered small light and power. For Fort Knox this number (the number of buildings as derived from Ref. (1)) is 1499.

AREA is the area (in square miles) of the community being served. From maps in Ref. (1), this value is determined to be 19 square miles.

ESRSM is the magnitude of annual energy sales to the small light and power customers (in units of 10^6 kilowatt-hours (KW·hr)). In order to understand the need for this parameter, a brief discussion of the purposes of the Fort Knox Total Energy System is required. A TES is designed as a power generation system which will supply all the energy needs of a community with both thermal and electrical energy. During the course of similar previous studies,[4] it was found that there exists an optimum thermal-electrical mix which would result in the best economics for the system. This mix is defined in terms of a percentage as follows: if the entire site were to have its space conditioning demand supplied by a high temperature water thermal utility system (TUS), then this is defined as the 100% case. In other words 100% of the heating and cooling load is supplied by the TUS. Conversely, the 0% case means that all the space conditioning load is supplied electrically, with no TUS. Thus, for example, the 80% case means that 80% of the Fort derives it space conditioning load from the TUS, and the remaining 20% is electrically heated and cooled. Of course, in all cases the non-space conditioning electric load (e.g., lights, motors, etc.) must be supplied by the power station. For the Fort Knox study, the 0%, 20%, 40%, 60%, 80% and 100% cases are of interest as a representative spectrum for two types of thermal utility systems (TUS). The first type is that where the TUS supplies heating in winter and cooling in summer by utilizing high temperature water to power heat exchangers or absorptive air conditioners as required. All domestic hot water is supplied electrically. The second type is that where the TUS supplies heating and hot water only; all cooling is supplied electrically by compressive air conditioners. The corresponding T&D costs are calculated for each TUS thermal-electrical supply demand ratio and for each type of TUS that meets that ratio. Note that the zero-percent thermal/electrical load split, i.e. an all-electric community, has the same configuration for each type of TUS. The base case costs, which is Fort Knox as it currently exists, is also computed.

Now, for each case, seasonal variations are studied. The power station requirements are analyzed for the peak winter day, peak summer day, average winter day, average summer day, winter-spring day, and spring-summer day. Thus, in order to determine the value of ESRSM, the annual electrical energy sales, the larger of the average winter or average summer day, is chosen and then multiplied by 365 days per year to produce the equivalent annual energy consumption. The peak energy demand days are not used since average annual consumption is required, and over-design would result from this use.

The remaining parameters are now given.

CUSLLP is the number of large light and power customers. Per the Fort Knox assumption in CUSRSM, this value is zero.

ESLLP is the annual energy sales for Fort Knox to CUSLLP. This value is also zero.

EST is the total annual energy sales to all ultimate customers, which is the sum of ESRSM and ESLLP, or in this case is just equal to ESRSM, in units of 10^6 KW·hr.

LD is the load density computed from the ratio EST/AREA, in units of 10^6 KW·hr/sq. mi.

CONST is a regional constant, which is set equal to 12486 for Kentucky.

3.2 Sample Equipment Calculations

In order for the reader to understand the computations and assumptions made, sample calculations for the Fort Knox base case and the 80% TUS case with absorptive air conditioning are given. The quantitites are calculated for the equipment requirements; the unit costs are given in Section 3.3; and the marginal costs are obtained in Section 3.4.

The data for the base case is as follows:

CUSRM = 1499

CUSLLP = 0.0

ESRM = 102.73 (10^6 KW·hr) derived from Ref. (1)

ESLLP = 0.0

EST = ESRSM + ESLLP = 102.73 (10^6 KW·hr)

AREA = 19 (square miles)

LD = EST/AREA = 5.41 (10^6 KW·hr/sq. mi.)

CONST = 12486

The equipment requirements are as follows:

A. TRANSMISSION LINES. For the base case it is assumed that transmission line costs are zero, since for any new TUS new transmission lines will have to be constructed. Thus, the marginal cost will include funds for building new transmission lines.

B. TRANSMISSION SUBSTATION CAPACITY. This quantity is measured in terms of Kilovolt-amperes (KVA) capacity in place. The regression formula is

TSUB = 674700 + ESRSM*712.5 + ESLLP*523.2

Using the Fort Knox data, the value of TSUB is obtained as 7.48×10^5 KVA.

C. PRIMARY DISTRIBUTION LINES. This quantity is measured in units of pole-miles, since the principal portion of investment in primary distribution systems is in the structures and easements. The formula for this cost factor, labeled "POLE" is:

POLE = CONST + ESRSM*0.9102 - LD*34306.

For Fort Knox, this cost is seen to be -8.6×10^5 POLE, reflecting the inappropriate application of a low-demand density correlation to a high demand-density situation.

Thus, another method of determining the equipment requirement of the primary distribution lines is required. One can assume that the primary distribution lines run in the same configuration as the thermal utility system (TUS) piping layout; thus the lengths of the TUS pipes can be used as a parameter to measure the required number of poles. The Fort Knox TUS contains 1.58×10^5 feet of piping. Now by assuming that the poles are 150 feet apart and dividing the total length of distribution lines (i.e. piping) by the 150 ft pole interval, a value of 1056 pole-miles is found.

Note that the Fort Knox distribution system is currently in existence and the equipment needed to upgrade the distribution system will consist of a few power transmission cables, the costs of which are small. Since the primary distribution requirement of 1056 poles will appear in all cases under analysis, including the base case, the marginal cost of upgrading the primary distribution system will be zero, as expected. Thus, the true value of the required distribution equipment is not important in this marginal analysis.

D. DISTRIBUTION SUBSTATION CAPACITY. This quantity is measured in terms of KVA capacity in place. The equation for this factor, labelled "DSUB," is:

DSUB = ESRSM*485.4 + AREA*9.46.

Thus, the required capacity for Fort Knox is computed to be 5.0×10^4 KVA.

E. LINE TRANSFORMERS. This quantity also is measured in KVA capacity in place. The formula is

LT = ESRSM*568.2 + ESLLP*102.6 + AREA*5.15

which gives LT = 5.85×10^4 KVA being required for Fort Knox.

F. METERS. Currently, at Fort Knox there are no individual residential electrical meters, and it is assumed that there will be none in the future.

The 80% TUS case with absorptive air conditioning is now examined. The data values are as follows:

CUSRSM = 1499

CUSLLP = 0.0

ESRSM = 176.23 (10^6 KW·hr)

ESLLP = 0.0

EST = ESRSM + ESLLP = 176.23 (10^6 KW·hr)

AREA = 19 (sq. mi.)

LD = EST/AREA = 9.28 (10^6 KW·hr/sq. mi.)

CONST = 12486.

The equipment requirements are computed as in the preceding example except as noted.

A. TRANSMISSION LINES. Actual data are used here rather than those of the stated formula. It is assumed that the transmission lines will be laid parallel to the primary TUS supply pipe from the power generation station to the Fort Knox community. This distance is 3.03 miles. Thus the requirement for transmission lines as measured in structure miles (analagous to pole-miles of the distribution system) is 3.03. This quantity does not change for each of the cases.

B. TRANSMISSION SUBSTATION CAPACITY. Using the case data and the previously noted equation for Fort Knox, TSUB is computed to be 8.00×10^5 KVA.

C. PRIMARY DISTRIBUTION LINES. This quantity is constant for all cases and is equal to 1056 pole-miles, as discussed previously.

D. DISTRIBUTION SUBSTATION CAPACITY. For Fort Knox, this quantity is calculated to be 8.572×10^4 KVA.

E. LINE TRANSFORMERS. For Fort Knox, this quantity is calculated to be 1.0023×10^5 KVA.

F. METERS. This value is zero for all cases, as explained in the previous discussion.

Tables 1 and 2 list all the equipment requirements as calculated.

3.3 Unit Equipment Costs

The costs of various Transmission and Distribution equipment items are complicated functions of equipment ratings, type of installation, and geographic region of the country. This complexity is further compounded by the diversity of equipment constructions, voltage levels, mounting possibilities, and phase characteristics. Reliable cost data are available for transmission lines, both above and below ground, but substation and distribution costs are not easily obtained. Conversations regarding these topics with representatives of the Boston Edison Company bore little fruit. It is for these reasons that this report again turns to the Baughman and Bottaro paper for the unit equipment costs. These authors performed a literature survey and developed equipment cost values which are compatible with the units of the equipment requirements. Table 3 lists these costs with the following modifications:

A. All costs listed are inflated to 1985 dollars using an 8% annual rate.

B. The costs stated in the original source vary regionally; as such, the data reflect those values applicable to Kentucky only.

C. The cost of transmission lines are obtained from Ref. (3) and are stated exclusive of land costs.

3.4 Marginal Equipment Costs

The capital and marginal equipment costs are now calculated. The capital cost is calculated by the expression

$$C = \sum_i R_i * U_i$$

where

C is the capital cost of the Transmission and Distribution system for a given thermal/electrical load split case;

R_i is the equipment requirement for the i^{th} item (e.g. line transformers); and

U_i is the unit cost of the i^{th} equipment item.

The marginal cost is computed as

$$M = C - C_{Base}$$

where

M is the marginal cost for upgrading the present (base) Transmission and Distribution system to the desired percent case,

C is defined above, and

C_{Base} is the capital cost of the base Transmission and Distribution system (i.e. Fort Knox as it exists today, if it were to be built in 1985).

Tables 4 and 5 list the results of the above calculations.

4. SUMMARY

Tables 4 and 5 list the results of this report. The following points should be noted:

A. The base case data do not include transmission lines. All other cases under study do include transmission lines, since they will have to be constructed;

B. All of Fort Knox is considered to consist of small light and power users;

C. The data were obtained from Ref. (1) except as noted; and

D. No residential meter costs are included in any of the analyses.

It is seen that the marginal costs of upgrading the Fort Knox Transmission and Distribution system are not insignificant in constructing an electric-intensive TES.

TABLE 1

TRANSMISSION AND DISTRIBUTION EQUIPMENT REQUIREMENTS FOR FORT KNOX ABSORPTIVE AIR CONDITIONING, ELECTRIC HOT WATER TUS

CASE / EQUIPMENT ITEM	BASE	100%	80%	60%	40%	20%	0%
Transmission Line (miles)	0	3.03	3.03	3.03	3.03	3.03	3.03
Transmission Substation Capacity ($KVA\times10^5$)	7.48	7.68	8.00	8.28	8.77	9.09	9.56
Distribution Line (pole-miles)	1056	1056	1056	1056	1056	1056	1056
Distribution Substation Capacity ($KVA\times10^4$)	5.00	6.38	8.57	10.45	13.77	15.96	19.15
Line Transformer Capacity ($KVA\times10^4$)	5.85	7.46	10.02	12.22	16.10	18.67	22.41
Number of Meters	0	0	0	0	0	0	0

TABLE 2

TRANSMISSION AND DISTRIBUTION EQUIPMENT REQUIREMENTS FOR FORT KNOX COMPRESSIVE AIR CONDITIONING, TUS SUPPLIED HOT WATER TUS

EQUIPMENT ITEM \ CASE	BASE	100%	80%	60%	40%	20%	0%
Transmission Line (miles)	0	3.03	3.03	3.03	3.03	3.03	3.03
Transmission Substation Capacity ($KVA \times 10^5$)	7.48	8.16	8.22	8.26	8.70	9.05	9.56
Distribution Line (pole-miles)	1056	1056	1056	1056	1056	1056	1056
Distribution Substation Capacity ($KVA \times 10^4$)	5.00	9.67	10.02	10.31	13.33	15.68	19.15
Line Transformer Capacity ($KVA \times 10^4$)	5.85	11.31	11.72	12.05	15.59	18.34	22.41
Number of Meters	0	0	0	0	0	0	0

TABLE 3

TRANSMISSION AND DISTRIBUTION EQUIPMENT
UNIT COSTS

ITEM	UNIT COST
Transmission Lines	$1.295\ 10^6$ \$/mile
Transmission Substation	13.09 \$/KVA
Primary Distribution Lines	$4.029\ 10^4$ \$/pole-mile
Distribution Substation	26.18 \$/KVA
Line Transformers	39.27 \$/KVA
Residential Meters	25.00 \$/meter

TABLE 4

TRANSMISSION AND DISTRIBUTION COSTS SUMMARY, FORT KNOX, ABSORPTIVE AIR CONDITIONING, ELECTRIC HOT WATER TUS

CASE	CAPITAL COST (millions of dollars)*	MARGINAL COST (millions of dollars)*
BASE	55.94	--
100%	61.12	5.18
80%	63.12	7.18
60%	64.84	8.90
40%	67.88	11.94
20%	69.88	13.94
0%	72.80	16.86

*All costs stated in 1985 dollars

TABLE 5

TRANSMISSION AND DISTRIBUTION COSTS SUMMARY,
FORT KNOX, COMPRESSIVE AIR CONDITIONING,
TUS SUPPLIED HOT WATER TUS

CASE	CAPITAL COSTS (millions of dollars)*	MARGINAL COSTS (millions of dollars)*
BASE	55.94	--
100%	64.12	8.18
80%	64.46	8.52
60%	64.71	8.77
40%	67.47	11.53
20%	69.62	13.68
0%	72.80	16.86

*all costs stated in 1985 dollars

REFERENCES

(1) Best, F. R., Goldman, S.B. and Golay, M.W., Final Report: Analysis of Nuclear and Coal Fueled Total Energy System Options for Ft. Knox, Kentucky, Contract No. DAAK02-74-C-0308, MIT Dept. of Nuclear Engineering, June 1977.

(2) Baughman, M.L., and Bottaro, D.J., Electric Power Transmission and Distribution Systems: Costs and Their Allocation, MIT Energy Laboratory Report No. MIT-EL-75-020.

(3) Annual Report of the Boston Edison Company to the Federal Power Commission, for the Year Ending December 31, 1975.

(4) Stetkar, J.W., Best, F.R., Golay, M.W., "Design of a Nuclear-Powered Total Energy System for Fort Bragg, North Carolina," Final Report under Contract No. DAAK02-74-C-0308, MIT, Department of Nuclear Engineering, May 1976.

FESA DISTRIBUTION

US Military Academy
ATTN: Dept of Mechanics
ATTN: Library
West Point, NY 10996

Chief of Engineers
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-FEB
ATTN: DAEN-FEP
ATTN: DAEN-FEU
ATTN: DAEN-FEZ-A
ATTN: DAEN-MCZ-S
ATTN: DAEN-MCE-U
ATTN: DAEN-MCZ-E
ATTN: DAEN-RDL
Dept of the Army
WASH, DC 20314

Director, USA-WES
ATTN: Library
P.O. Box 631
Vicksburg, MS 39181

Commander, TRADOC
Office of the Engineer
ATTN: ATEN
ATTN: ATEN-FE-U
Ft. Monroe, VA 23651

US Army Engr Dist, New York
ATTN: NANEN-E
26 Federal Plaza
New York, NY 10007

USA Engr Dist, Baltimore
ATTN: Chief, Engr Div
P.O. Box 1715
Baltimore, MD 21203

USA Engr Dist, Charleston
ATTN: Chief, Engr Div
P.O. Box 919
Charleston, SC 29402

USA Engr Dist, Savannah
ATTN: Chief, SASAS-L
P.O. Box 889
Savannah, GA 31402

USA Engr Dist Detroit
P.O. Box 1027
Detroit, MI 48231

USA Engr Dist Kansas City
ATTN: Chief, Engr Div
700 Federal Office Bldg
601 E. 12th St
Kansas City, MO 64106

USA Engr Dist, Omaha
ATTN: Chief, Engr Div
7410 USOP and Courthouse
215 N. 17th St
Omaha, NM 68102

USA Engr Dist, Fort Worth
ATTN: Chief, SWFED-D
ATTN: Chief, SWFED-MA/MR
P.O. Box 17300
Fort Worth, TX 76102

USA Engr Dist, Sacramento
ATTN: Chief, SPKED-D
650 Capitol Mall
Sacramento, CA 95814

USA Engr Dist, Far East
ATTN: Chief, Engr Div
APO San Francisco, CA 96301

USA Engr Dist, Japan
APO San Francisco, CA 96343

USA Engr Div, Europe
European Div, Corps of Engineers
APO New York, NY 09757

USA Engr Div, North Atlantic
ATTN: Chief, NADEN-T
90 Church St
New York, NY 10007

USA Engr Div, South Atlantic
ATTN: Chief, SAEN-TE
510 Title Bldg
30 Pryor St, SW
Atlanta, GA 30303

USA Engr Dist, Mobile
ATTN: Chief, SAMEN-C
P.O. Box 2288
Mobile, AL 36601

USA Engr Dist, Louisville
ATTN: Chief, Engr Div
P.O. Box 59
Louisville, KY 40201

USA Engr Dist, Norfolk
ATTN: Chief, NAOEN-D
803 Front Street
Norfolk, VA 23510

USA Engr Div, Missouri River
ATTN: Chief, Engr Div
P.O. Box 103 Downtown Station
Omaha, NB 68101

USA Engr Div, South Pacific
ATTN: Chief, SPDED-TG
630 Sansome St, Rm 1216
San Francisco, CA 94111

AF Civil Engr Center/XRL
Tyndall AFB, FL 32401

Naval Facilities Engr Command
ATTN: Code 04
200 Stovall St.
Alexandria, VA 22332

Defense Documentation Center
ATTN: TCA (12)
Cameron Station
Alexandria, VA 22314

Commander and Director
USA Cold Regions Research Engineering
Laboratory
Hanover, NH 03755

USA Engr Div, Huntsville
ATTN: Chief, HNDED-ME
P.O. Box 1600 West Station
Huntsville, AL 35807

USA Engr Div, Ohio River
ATTN: Chief, Engr Div
P.O. Box 1159
Cincinnati, OH 45201

USA Engr Div, North Central
ATTN: Chief, Engr Div
536 S. Clark St
Chicago, IL 60605

USA Engr Div, Southwestern
ATTN: Chief, SWDED-TM
Main Tower Bldg, 1200 Main St
Dallas, TX 75202

USA Engr Div, Pacific Ocean
ATTN: Chief, Engr Div
APO San Francisco, CA 96558

FORSCOM
ATTN: AFEN
ATTN: AFEN-FE
Ft. McPherson, GA 30330

Officer in Charge
Civil Engineering Laboratory
Naval Construction Battalion Center
ATTN: Library (Code L08A)
Port Hueneme, CA 93043

Commander and Director
USA Construction Engineering
Research Laboratory
P.O. Box 4005
Champaign, IL 61820